

# Determination of Site-specific NPK Fertilizer Rates for Rice Grown on Tidal Lowland

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## ABSTRACT

This research aimed to determine site specific NPK fertilizer rates combined with rice straw compost application for rice grown on the tidal lowland. This research was conducted in a greenhouse in Indralaya, Ogan Ilir, South Sumatera in February until September 2017 using a factorial completely randomized design with two factors and three replications. The first factor was NPK fertilizer rate calculated based on the results of soil chemical analysis, consisting of five levels, namely 50% ( $D_1$ ), 75% ( $D_2$ ), 100% ( $D_3$ ), 125% ( $D_4$ ) and 150% ( $D_5$ ) of the site-specific fertilizer rate. The second factor was rice straw compost rate consisting of two levels, namely 5 Mg ha<sup>-1</sup> ( $J_1$ ) and 10 Mg ha<sup>-1</sup> ( $J_2$ ). The results showed that the application of 150% NPK rate and 10 Mg ha<sup>-1</sup> rice straw compost resulted in the best effects on the rice growth grown on the tidal lowland. The application of those fertilizer doses produced the highest maximum number of tillers and productive tillers. In this regard the doses of NPK fertilizers that should be applied are 315 kg urea ha<sup>-1</sup>, 135 kg SP-36 ha<sup>-1</sup> and 90 kg KCl ha<sup>-1</sup>.

**Keywords:** Fertilization, rice, rice straw compost, site-specific, tidal lowland

## ABSTRAK

Penelitian ini bertujuan untuk menentukan dosis pupuk NPK spesifik lokasi yang dikombinasikan dengan aplikasi kompos jerami pada padi rawa pasang surut. Penelitian ini dilaksanakan pada bulan Februari sampai September 2017 di rumah kaca, Indralaya, Ogan Ilir. Penelitian ini menggunakan rancangan acak lengkap faktorial dengan dua faktor perlakuan yaitu dosis pupuk NPK spesifik lokasi dan dosis kompos jerami padi, setiap perlakuan terdiri dari 3 ulangan. Dosis pupuk NPK spesifik lokasi terdiri dari lima taraf yaitu  $D_1$  (Dosis NPK 50%),  $D_2$  (Dosis NPK 75%),  $D_3$  (Dosis NPK 100%),  $D_4$  (Dosis NPK 125%) dan  $D_5$  (Dosis NPK 150%). Dosis kompos jerami terdiri dari dua taraf yaitu  $J_1$  (Dosis kompos jerami 5 Mg ha<sup>-1</sup>) dan  $J_2$  (Dosis kompos jerami 10 Mg ha<sup>-1</sup>). Hasil penelitian menunjukkan bahwa dosis pupuk NPK spesifik lokasi untuk pertumbuhan tanaman padi rawa yaitu dosis NPK 150% dan dosis kompos jerami 10 Mg ha<sup>-1</sup>. Hal ini ditunjukkan pada jumlah anakan maksimum dan anakan produktif tertinggi pada tanaman padi. Pupuk NPK spesifik lokasi untuk pertumbuhan tanaman padi yaitu Urea 315 kg ha<sup>-1</sup>, SP-36 135 kg ha<sup>-1</sup> dan KCl 90 kg ha<sup>-1</sup>.

**Kata Kunci:** Kompos jerami, padi, pemupukan, spesifik lokasi, pasang surut

## INTRODUCTION

The number of productive agricultural land in Indonesia has reduced due to land use changes for many purposes. Therefore, the extensification of rice cultivation can only be directed to sub-optimal land, such as tidal swampland. The area of wetlands in Indonesia is about 33.4 million ha (BBPPSLP 2006),

consisting of about 8.35 million ha tidal lowland, 11.4 million ha swampland and 14.92 million ha peatland (BBSLDP 2014). One type of swampland is the tidal lowland. The area of tidal lowland in Indonesia is about 10.8% of total land area in Indonesia (Rahmawaty *et al.* 2014). Around 9.53 million ha of them are potentially developed for agricultural land (Badan Litbang Pertanian 2007). Tidal lowland is very potential to be utilized for agricultural cultivation, especially for rice plants, in which the rice is the staple food for Indonesian and because of the

increasing food demand with the increase of population in Indonesia.

The development of tidal lowland for agricultural puposes faces various constraints, *i.e.* low soil pH, low nutrient availability, high content of toxic compounds for plants such as  $\text{Fe}^{2+}$ ,  $\text{Al}^{3+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{H}_2\text{S}$  and Na, and high level of  $\text{FeS}_2$  (the level of  $\text{FeS}_2$  above 200 ppm will disturb plant growth), low N, P and K contents, and high Cu and Zn contents (Sesbany and Vandalisma 2000). Therefore, an appropriate management of tidal lowland is necessary to overcome various constraints in the utilization of this type of land.

The fertility status of tidal lowland can be improved by applying an optimum fertilization (Direktorat Jenderal Tanaman Pangan 2013). Fertilization aims to provide nutrients to support the growth and yields of plants (Suryana 2004). Efficient use of N, P, and K fertilizers on rice plants aims to increase the grain yields and reduce the residual impact of fertilizer on the environment due to the excessive use of chemical fertilizers. Deficiency of N, P, and K nutrients will cause less optimum on plant growth, while the excessive amount of N, P, K nutrients can both inhibit plant growth and cause environmental pollution (Duan *et al.* 2007). The toxicity and excessive amounts of nutrients can lead to the low plant yields.

Nutrient imbalance in soil and decreasing soil organic matter content can level off rice yields (Budianto 2002). In time, this condition can decrease the national rice production. The leveling off of rice yields is due to the large quantities of nutrients have been taken out of the soil through harvested crops and only the less amount of nutrients has been given back to the soil. Therefore, soil nutrient management and organic material application on soil are necessary to improve crop productivity.

According to Roesmarkam and Yuwono (2002), organic materials can increase soil CEC, bind K that is susceptible to leaching and fixation by clay minerals. One source of organic materials derived from the rice cultivation is rice straw that can be composted. Rice straw can be utilized as the source of organic matter for soil microbes and the source of nutrients for plants. Rice straw application is necessary to improve fertilizer efficiency (Departemen Pertanian 2008). Returning of biomass of rice straw is a way to restore soil organic matter content. The study of Jumberi *et al.* (1998) shows that the application of 4  $\text{Mg ha}^{-1}$  rice straw compost on tidal lowland can reduce Fe and  $\text{SO}_4$  content, increase K availability and rice yield. Moreover, application of 5  $\text{Mg ha}^{-1}$  straw compost can increase rice yield up to 34.39% (Rosiana *et al.* 2013).

Each region has different soil fertility characteristics (Setiawan *et al.* 2014), so that the recommended fertilizer rate is less relevant to the varying soil fertility conditions in each region (Adbyana 2011). Therefore, fertilization rate should be adjusted to nutrient status in soil (Hatta and Sulakhudin 2016). Excessive fertilization causes nutrient imbalance, destroys the physical and chemical properties of soil, pollutes the environment and increases  $\text{CH}_4$  and  $\text{N}_2\text{O}$  emissions (Das and Adhya 2014). Excessive use of fertilizer by farmers cannot be avoided (Endrizal and Julistia 2004). The current rate of fertilizer by farmers reaches 400 up to 600  $\text{kg urea ha}^{-1}$ , more than the recommended rate by Indonesian government, *i.e.* 200 up to 260  $\text{kg urea ha}^{-1}$  (Abdul 2003). Site-specific fertilization is a balanced and rational fertilization based on the nutrient needs at specific sites (Doberman *et al.* 2004). This study aims to determine the site-specific rate of NPK fertilizers for rice plants applied with rice straw compost, so that the fertilization can be more efficient and can increase rice productivity in the tidal lowland.

## MATERIALS AND METHODS

### Study Site

This study was conducted in February until September 2017 in the greenhouse of the Department of Soil Science, Faculty of Agriculture, Sriwijaya University.

### Research Design

The study was conducted using a factorial completely randomized design with two factors and three replications. The first factor was NPK fertilizer rate consisting of five levels, namely 50% of site-specific fertilizer rate ( $D_1$ ), 75% of site-specific fertilizer rate ( $D_2$ ), 100% of site-specific fertilizer rate ( $D_3$ ), 125% of site-specific fertilizer rate ( $D_4$ ) and 150% of site-specific fertilizer rate ( $D_5$ ). The second factor was rice straw compost rate consisting of two levels, *i.e.* 5  $\text{Mg ha}^{-1}$  ( $J_1$ ) and 10  $\text{Mg ha}^{-1}$  ( $J_2$ ).

The rice straw was composted using BeKa activator with doses of 1 ton of rice straw and 1 L of BeKa solution. The rice straw was chopped and mixed with BeKa activator and incubated for 2 months. The organic-C content in the straw compost was 18.312%; the total-N content was 1.932%; the amount of available-P was 0.352%; the amount of exchangeable-K was 2.250% and the C/N ratio was 9.47.

## Soil Sampling and Fertilization

The soil samples were taken in the tidal lowland (typology A) in Mulia Sari Village, Tanjung Lago, Banyuasin Regency, South Sumatra Province. The composite soil samples were taken from topsoils at a depth of 0 - 20 cm located at 02°41'24" S and 104°45'25" E. The soil properties including pH, the contents of N, P, K, Na, Ca, and Mg, CEC, exchangeable Al, exchangeable H and soil texture were measured. The amounts of total-N, available-P and exchangeable-K in the soils were used as references to calculate site-specific fertilizer requirement for rice plants. The rice straw compost was applied two weeks before planting. Urea fertilizer was applied three times, *i.e.* during planting, 14 days after planting and 28 days after planting. SP-36 and KCl Fertilizers were applied during planting time. The urea, SP-36 and KCl fertilizers and rice straw compost were given based on the calculation of fertilizer requirement. The site specific fertilizer rates were 210 kg urea ha<sup>-1</sup>, 90 kg SP-36 ha<sup>-1</sup> and 60 kg KCl ha<sup>-1</sup>.

## Planting and Measurement of Plant Parameters

The rice seed used in the experiment was INPARA 4 variety. The seeds were sown in a tray containing the planting medium of the mixture of soil, sand, and compost. After 2 weeks, the seedlings were transferred into pots containing of 10 kg soil

for each pot. The plant parameters measured were plant height (cm), maximum number of tillers and number of productive tillers. The plant height and the maximum number of tillers were determined during the primordial stage of rice plants. The number of productive tillers counted was referred to the number of tillers that produced panicles.

## Data Analysis

The data were analysed using F test and further tested using least significant difference (LSD) at 5% significance level.

## RESULTS AND DISCUSSION

### Soil Characteristics

The soil was collected from the tidal lowland with A typology (*i.e.* flooding during high tide and low tide). The soil was classified into acid sulphate soil. The characteristics of the soil are pH H<sub>2</sub>O (1:1) 4.57 (acid), pH KCl (1:1) 3.94, organic-C 51.43 g kg<sup>-1</sup> (very high), total-N 1.68 g kg<sup>-1</sup> (low), available-P (Bray 1) 9.40 mg kg<sup>-1</sup> (medium), exchangeable-K 0.28 cmol(+) kg<sup>-1</sup> (low), exchangeable-Na 0.65 cmol(+) kg<sup>-1</sup> (medium), exchangeable-Ca 0.48 cmol(+) kg<sup>-1</sup> (low), exchangeable-Mg 0.25 cmol(+) kg<sup>-1</sup> (very low), CEC 15.23 cmol(+) kg<sup>-1</sup> (low), exchangeable-Al 4.96 cmol(+) kg<sup>-1</sup>, exchangeable-H 2.61 cmol(+) kg<sup>-1</sup>, soil texture sandy clay containing of 53.96% sand, 32.09% silt and 13.95%

Table 1. Characteristics of the soil used in the experiment.

Parameters	Unit	Value*	Level**
pH H <sub>2</sub> O (1:1)		4.57	Acid
pH KCl (1:1)		3.94	
Organic carbon	g kg <sup>-1</sup>	51.43	Very high
Total-N	g kg <sup>-1</sup>	1.68	Low
Available-P (Bray I)	mg kg <sup>-1</sup>	9.40	Medium
Exchangeable- K	cmol(+) kg <sup>-1</sup>	0.28	Low
Na	cmol(+) kg <sup>-1</sup>	0.65	Medium
Ca	cmol(+) kg <sup>-1</sup>	0.48	Low
Mg	cmol(+) kg <sup>-1</sup>	0.25	Very low
Cation exchange capacity	cmol(+) kg <sup>-1</sup>	15.23	Low
Al	cmol(+) kg <sup>-1</sup>	4.96	
H	cmol(+) kg <sup>-1</sup>	2.61	
Soil texture:			Sandy Loam
Sand	%	53.96	
Silt	%	32.09	
Clay	%	13.95	

Note: \*\* Based on the criteria of soil characteristics proposed by Soil Research Institute (1983).

clay (Table 1). High soil organic matter content can improve fertilizer efficiency (Asmin and Karimuna 2014). According to Sutanto (2002), if the N content in soil is  $<0.25\%$  then the rice plants will experience N deficiency thus disrupting their growth. The low availability of P in the soil used in the current study is closely related to the high content of Al causing the P fixation by Al, so that the P is not available for crop uptake (Adiningsih 2005). The critical limit of exchangeable-K for paddy soil is  $0.20 \text{ cmol}(+) \text{ kg}^{-1}$  (Wihardjaka *et al.* 2002).

### Maximum Plant Height (Primordial Stage)

The results of analysis of variance shows that the NPK fertilizer rate, the straw compost rate and the interaction of the two factors did not significantly affect the maximum plant height measured in the primordial stage (Table 2). The application of 125% NPK fertilizer rate resulted in the highest plant height (*i.e.* 88.83 cm), but the application of 100% fertilizer rate resulted in the lowest plant height, *i.e.* 79.67 cm. The application of straw compost at  $10 \text{ Mg ha}^{-1}$  resulted in a higher plant height than that in the application of  $5 \text{ Mg ha}^{-1}$ . The plant heights measured in the application of  $10 \text{ Mg ha}^{-1}$  and  $5 \text{ Mg ha}^{-1}$  straw compost were 85.80 cm and 82.77 cm, respectively (Table 2).

The combination of 150% NPK rate and  $5 \text{ Mg ha}^{-1}$  rice straw compost in the  $D_5J_1$  treatment resulted in the highest plant height, *i.e.* 89.50 cm and the lowest plant height was measured in the combination of 100% NPK rate and  $5 \text{ Mg ha}^{-1}$  rice straw compost ( $D_3J_1$  treatment), *i.e.* 76.67 cm. In general the height of INPARA 4 variety is 94 cm (Balai Benih Padi, 2009). The height of rice plant of INPARA 4 variety measured in the current study did not correspond to the description of rice plant of INPARA 4 variety proposed by Balai Benih Padi (2009). The plant height is influenced by internal and external factors as well as genetic factors, temperature, water condition, light intensity and N content in soil. Nitrogen (N) is the most important

nutrient for plants and the response of plants to N is greater than that of P and K (Gani and Sembiring 2007).

Based on the Standard Evaluation System for Rice, the height of rice plant is classified into 3 categories, namely low ( $<100 \text{ cm}$ ), medium (110 up to 130 cm) and high ( $>130 \text{ cm}$ ) (IRRI 1996). The INPARA 4 variety belongs to the low plant height category (plant height  $<100 \text{ cm}$ ). The height of rice plant is positively correlated to the leaf area in conducting photosynthesis. Plant height is used as one of the parameters of plant growth, but the high rate of plant growth does not necessarily result in a high yield. Plant height is negatively correlated to the rice yield (Djufry and Kasim 2015).

Plant height is influenced by varieties, this is because each variety has different genetic factors and characters (the presence of genes that control the properties of the varieties). In addition to its genetic properties, the environmental factors, such as climate, soil and biotic factors also affect the plant height (Sugeng 2001). Differences in growth and yields obtained are thought to be caused by one or more of these factors (Gardner *et al.* 1991). The increase in plant height observed in the current study is due to the increased availability of N in the soil and P uptake by plants due to NPK fertilization. In addition, the straw compost contains macronutrients N, P, and K, and micronutrients Fe, Zn that are available and absorbed by plants during the vegetative plant growth (Kaya 2013). Nitrogen plays a role in the formation of proteins and chlorophyll, P acts as an energy source for the vegetative plant growth, and K plays a role in the formation of proteins and carbohydrates (Hadisuwito 2007).

### Number of Tillers

Based on the analysis of variance, both the dosage of NPK fertilizers and the dosage of straw compost showed a significant effect on the number of tillers of rice plants (Table 3). The interaction between the two factors did not significantly affect

Table 2. The effect of the site-specific NPK fertilization and rice straw compost application on the maximum plant height (cm) measured in the primordial stage of rice plants.

Treatment	Rice Straw Compost		Main Factor of
Dose of NPK	J <sub>1</sub> ( $5 \text{ Mg ha}^{-1}$ )	J <sub>2</sub> ( $10 \text{ Mg ha}^{-1}$ )	NPK Dose
D <sub>1</sub> (50%)	77.67	84.33	81.00
D <sub>2</sub> (75%)	81.33	87.67	84.50
D <sub>3</sub> (100%)	76.67	83.00	79.67
D <sub>4</sub> (125%)	88.67	89.00	88.83
D <sub>5</sub> (150%)	89.50	85.33	87.42
Main Factor of Rice Straw Compost	82.77	85.80	84.28

Table 3. The effect of site-specific NPK fertilization and rice straw compost application on the maximum number of tillers of rice plants.

Treatment	Rice Straw Compost		Main factor of NPK
Dose of NPK	J <sub>1</sub> (5 Mg ha <sup>-1</sup> )	J <sub>2</sub> (10 Mg ha <sup>-1</sup> )	Dose
D <sub>1</sub> (50%)	21.67	27.00	24.33a
D <sub>2</sub> (75%)	26.67	32.00	29.33ab
D <sub>3</sub> (100%)	28.67	31.00	29.83ab
D <sub>4</sub> (125%)	33.67	37.00	35.17b
D <sub>5</sub> (150%)	32.00	39.33	35.67b
Main factor of Straw Compost	21.67a	27.00b	LSD 0.05 = 6.29
	LSD 0.05 = 3.98		

Note: The values followed by different letters indicate significantly different based on LSD test at 5% level.

the average maximum number of tillers. The highest dose of NPK fertilizer (150% NPK rate) resulted in the highest maximum number of tillers, *i.e.* 35.67 and the lowest NPK fertilizer dosage (50% NPK rate) resulted in the lowest maximum number of tillers, *i.e.* 24.33. The application of 10 Mg ha<sup>-1</sup> straw compost resulted in a higher number of tillers than that in the application of 5 Mg ha<sup>-1</sup> straw compost. The results showed that the higher rates of the fertilizers applied to the soil, the more positive of the rice plants in giving response on the increase of the number of tillers (Table 3).

The highest maximum number of tillers measured during the primordial stage of rice plants was observed in the combination of 150% NPK rate and 10 Mg ha<sup>-1</sup> straw compost (D<sub>5</sub>J<sub>2</sub> treatment), *i.e.* 39.33, and the lowest maximum number of tillers was observed in the combination of 50% NPK rate and 5 Mg ha<sup>-1</sup> rice straw compost (D<sub>1</sub>J<sub>1</sub> treatment), *i.e.* 21.67.

The number of maximum tillers of INPARA 4 variety measured in the study of Yartiwi *et al.* (2012) is 22.80. The average of the maximum number of tillers according to the description of INPARA 4 variety proposed by Balai Benih Padi (2009) is 18.

The increase of NPK fertilizer dose more than 100% NPK rate resulted in a positive response of the rice plants on the fertilization, so that the maximum number of tillers exceeds the average number of tillers described for the INPARA 4 variety.

Deficiency of N and P on the rice plants can inhibit the formation of tillers (Gani and Sembiring 2007). The more N and P that can be absorbed by the rice plants, the more number of tillers that are formed. Nitrogen is the most important nutrient for plants and the response of rice plants to N is usually higher than that to P and K. Based on the results of current study, the maximum number of tillers of the rice plants applied with higher doses of fertilizers showed a positive response. Plants applied with high fertilizer doses resulted in the high maximum number of tillers.

The number of tillers formed is influenced by the vigor of different tillers by varieties. The formation of tillers is influenced by planting space and soil fertility (Nemoto *et al.* 1995, Counce *et al.* 2000). In the current study, the number of seeds planted was only one seed in each pot, therefore this condition can reduce the density of plants and increase the formation of tillers up to tenfold. When

Table 4. The effect of site-specific NPK fertilization and rice straw compost application on the number of productive tillers of rice plants.

Treatment	Rice Straw Compost		Main factor of
Dose of NPK	J <sub>1</sub> (5 Mg ha <sup>-1</sup> )	J <sub>2</sub> (10 Mg ha <sup>-1</sup> )	NPK Dose
D <sub>1</sub> (50%)	22.00	28.67	25.33a
D <sub>2</sub> (75%)	27.00	27.33	27.17a
D <sub>3</sub> (100%)	29.33	29.00	29.17a
D <sub>4</sub> (125%)	34.67	37.00	35.67b
D <sub>5</sub> (150%)	30.00	39.33	34.67b
Main factor of Straw	28.60a	32.20b	LSD 0.05 = 5.34
Compost	LSD 0.05 = 3.38		

the soil fertility status was increased due to higher doses of NPK fertilizers and straw compost applied, there were more number of tillers produced.

### Number of Productive Tillers

Based on the results of analysis of variance, the rate of NPK fertilizer showed a very significant effect on the number of productive tillers of rice plants, and the rate of straw compost showed a significant effect on the number of productive tillers (Table 4). The interaction between the two factors were not significantly affect the average number of productive tillers of rice plants. The application of 125% NPK rate resulted in the highest number of productive tillers, *i.e.* 35.67 and the lowest NPK fertilizer rate (50% NPK rate) resulted in the lowest number of productive tillers, *i.e.* 25.33. The application of 10 Mg ha<sup>-1</sup> straw compost resulted in a higher yield than the application of 5 Mg ha<sup>-1</sup> straw compost. The the average number of productive tillers of the rice plants applied with 10 Mg ha<sup>-1</sup> straw compost was 32.20, whereas the average number of productive tillers of the rice plants applied with 5 Mg ha<sup>-1</sup> straw compost was 28.60.

The highest number of productive tillers measured during the generative phase of the rice plants was observed in the D<sub>5</sub>J<sub>2</sub> treatment (150% NPK rate and 10 Mg ha<sup>-1</sup> rice straw compost), *i.e.* 39.33, and the lowest number of productive tillers was observed in the treatment D<sub>1</sub>J<sub>1</sub> (50% NPK rate and 5 Mg ha<sup>-1</sup> rice straw compost), *i.e.* 22.

The number of productive tillers of INPARA 4 variety described by Balai Benih Padi (2009) is 18. The results of the current study showed that the highest number of productive tillers reached 39, exceeding the number of productive tillers of INPARA 4 variety described by Balai Benih Padi (2009). The ability of rice plants to form productive tillers is influenced by the interaction of genetic traits, varieties and environmental factors (Endrizal and Bobihoe 2010). The increasing number of tillers was obvious in each fertilization treatment with the tendency of the higher dose of the fertilizer applied, the more number of the tillers produced.

The number of productive tillers is determined by the number of tillers that grows before the primordial phase of rice plants. The seedlings can potentially form panicles or do not form panicles (Soemartono *et al.* 1984). The formation of panicles is influenced by the optimum planting distance and available nutrients in soil, so that the root growth and plant canopy do not compete to each other, resulting in higher number of productive tillers (Suparyono and Setyono 1993).

## CONCLUSIONS

The results showed that the application of 150% NPK rate (315 kg urea ha<sup>-1</sup>, 35 kg SP-36 ha<sup>-1</sup> and 90 kg KCl ha<sup>-1</sup>) combined with 10 Mg ha<sup>-1</sup> rice straw compost resulted in the best effects on the growth of rice plants grown on the tidal lowland. The application of those fertilizer doses produced the highest both maximum number of tillers and productive tillers.

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